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The Brightness and Legibility at Night of Road Traffic Signs*

By J. S. SMYTH, B.Sc., A.M.I.E.E. *(Member)*

Synopsis

An investigation to determine the most satisfactory brightness of lettered signs seen against different background brightness levels is described. "Ideal" sign brightnesses are suggested, lying between the minimum for threshold legibility and the maximum acceptable without ill effects from glare. The ideal brightness for legibility was found to be unaffected by the colour of the sign, and was the same for black on white or white on black signs. The effect of disturbing factors such as glare from automobile headlights, and dirt collection on the sign are considered; such handicaps do not affect legibility distance very greatly, but may seriously reduce the conspicuity of the sign.

The second part of the paper gives an account of a study of reflex reflecting lensed symbols used on traffic signs: methods of fitting lenses, and small modifications to some symbols are suggested to make recognition easier.

The work described was carried out by a technical committee, called by the Illuminating Engineering Society at the request of the Ministry of Transport. The results have led to some recommendations made in the Departmental Report on Traffic Signs, 1944.

Introduction

The "Report of the Departmental Committee on Traffic Signs, 1933," exhaustive though it was, gave little guidance on the brightness of illuminated signs; thus, when a further committee was appointed in February, 1943, to consider the system of road traffic signs, it was necessary to break new ground and investigate sign brightness and legibility. Sir Frederick Cook, chairman of the new committee, approached the Illuminating Engineering Society, which undertook to form a technical sub-committee to study the problem. In addition, information on the best method of fitting reflecting lenses to certain symbols was required. Due to the courtesy of the Minister of Transport, it is now possible to describe the work of the technical sub-committee which met at intervals from September, 1943, to March, 1944. Their work, as here discussed, fell under two headings, (I) the problem of the brightness of lettered signs, and (II) experiments made on symbols fitted with reflecting lenses.

PART 1

THE BRIGHTNESS AND LEGIBILITY OF LETTERED SIGNS

(1) The Problem

The problem, as originally put to the technical sub-committee, was closely defined. The size of the lettering and spacing were determined by existing

* Communication from the Staff of the Research Laboratories of The General Electric Company, Limited, Wembley, England.

This paper is based on the research conducted in the Research Laboratories of The General Electric Company Limited, a report on which was presented by a technical sub-committee of the Illuminating Engineering Society to the Ministry of Transport in 1944.

Manuscript received on December 10, 1946. Paper presented to a meeting of the Society on Tuesday, February 11, 1947.

In the absence of Mr. J. S. Smyth, the paper was read by Mr. W. R. Stevens.

signs, which, it was known, could be read in daylight at some 50 feet distance for each inch of letter height; by night the same range of legibility was desirable.

Some problems were specifically stated; investigation was required into:—

(1) The sign brightness necessary to secure adequate conspicuity and legibility with different background brightnesses.
(2) The relation between sign brightness and legibility distance.
(3) The relative merits of internally and externally illuminated signs.
(4) The relative merits of dark lettering on a light background and vice versa.
(5) The siting of signs in relation to the background generally and to other light sources in particular.

Other matters affecting the major problems included the use of coloured signs, the effect of glare, and the loss of contrast due to dirt collection on the face of the sign. Thus even when the dynamic effects occurring in the street were excluded, many factors could influence the optimum brightness, and it was decided therefore to investigate the main problem in the simplest conditions compatible with realism, and then to study the effect of disturbing factors such as glare. It was realised that existing fundamental data on visual acuity and glare could probably provide answers to some of the questions posed, and, indeed, some of the data obtained experimentally was but a confirmation of existing knowledge, as will be seen later. (See Appendix I.) Nevertheless, the results of the investigation were to be submitted to a committee, not exclusively illuminating engineers, and it was felt that data obtained from equipment closely simulating full-scale conditions would be more readily acceptable.

(2) Experimental Approach

In 1943 it was impossible to carry out lengthy investigations on the open highway; fortunately an investigation of this nature may well be better confined to the laboratory, where the easier control of conditions and more comfortable surroundings permit the amassing of an amount of data impossible to obtain in a reasonable period out of doors. It was, of course, very desirable that the laboratory equipment should simulate as closely as possible the conditions found in a peacetime street scene, and the precautions taken to produce a close approximation to the brightness pattern of the street are described later.

It was possible at the outset to lay down certain simplifying conditions:—

(1) The night-time legibility distance must approach that in daylight, viz. about 50 feet per inch height of letter, using the standard alphabet given in the 1933 Report.(1)
(2) No attempt was made to estimate the brightness desirable to draw attention to a sign in a brightly-lit shopping centre. In these surroundings the desirable brightness must depend on local conditions, and the nature of these is not such as may be reproduced in the laboratory.
(3) At brightness levels below that equivalent to "half-moon," headlights are used in open country, and the brightness of signs need, therefore, not be adapted to the unrelieved darkness of a heavily overcast or moonless night.

Condition (1) at once reduced the number of variables to be investigated. It was only necessary to examine the behaviour of a single letter size, say 3 inches high, at a distance of 150 feet (to scale); any conclusions drawn as to the brightness are equally applicable to a sign with letter size, say 6 inches, at a distance of 300 feet, since, at the minimum acceptable legibility distance, the angle subtended at the eye by the letters is constant for all signs. This

(a) Laboratory set-up.

(b) Original street.

Fig. 1. Street scene for observations.

ignores the effect of mist, which reduces the legibility of large distant signs to a greater extent than that of smaller, nearer signs; this effect, however, is not one which can be overcome by an increase in brightness.

Conditions (2) and (3) limited the range of background brightness from "half-moon" to full street lighting.

It was clearly desirable to determine the range in sign brightness which could be accepted at any general level of background brightness; three criteria were therefore laid down for the guidance of observers:—

(A) The minimum sign brightness at which the legend could be read at a distance of 50 feet for each inch of letter height.

(B) The maximum brightness acceptable, determined either by the observer's sense of discomfort or by loss of background detail beyond the sign due to glare.

(C) The "ideal" brightness, determined purely by personal judgment. The value chosen for C naturally lay between the previous two.

The six observers who took part in the investigation all had "normal" eyesight, that is to say that, with glasses if worn, they were able in daylight to read 3-inch lettering at a distance of 150 feet. It might be expected, therefore, that for criterion A they would be in close agreement, and this was found to be so. More surprising was the very close agreement on criterion C, the "ideal" brightness, which did not involve a "threshold." All observers were experienced in this type of work, and were skilled in holding a criterion.

(3) Experimental Technique

(i) Representation of the Street Scene

The construction of a scale model was considered, but the practical difficulties of reproducing a true brightness pattern, including the sky and buildings, were such that the idea was quickly discarded in favour of the projection upon a screen of the view of a peace-time street-lighting installation. The scene chosen (Castelnau, Barnes, Fig. 1) is typical of the English residential road, and there were available lantern slides made under controlled conditions to give a close reproduction of the brightness range existing in the original. Clearly, no projected scene can reproduce by itself the effect of glare from the lamps of the street-lighting installation, and these were therefore simulated by small sources of light placed behind holes in the screen; the

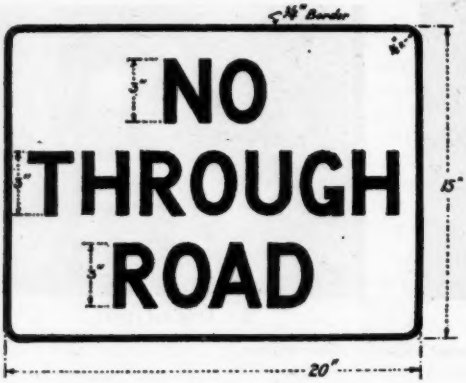

Fig. 2. Sign for legibility observations.

intensities of these sources were individually adjusted to produce at the eye of the observer the illumination which would obtain in practice.

The sign chosen, "NO THROUGH ROAD" (see Fig. 2), was reproduced photographically (both as black on white and as white on black) from the figure given in the 1933 Departmental Report. Reproductions to different scales were made, but, in fact, it was found that the distance of legibility was controlled largely, at sign brightnesses of a reasonable order, by the letter size, and in the bulk of the experiments only one size was used, equivalent to 3-inch letters at 50 yards, or, for that matter, to 6-inch letters viewed at 100 yards. The sign was mounted in a rectangle cut out of the screen at the appropriate position, and backed by an opal panel whose brightness could be varied over a wide range.

For lower levels of background brightness, the whole level of screen brightness and street lamp intensities was reduced, while for still lower levels (moon and half-moon) a lantern slide of a daylight street scene was used, with the brightness reduced appropriately.

The whole arrangement, viewed at a distance to give the correct perspective, gave a very realistic representation of a street, so far as observers could recall after four years of blackout.

A comparison may be seen in Fig. 1 between the original photograph of the street and a photograph of the scene as reproduced in the Laboratory.

(2) Observations

A series of preliminary observations was made to establish a suitable technique of observation; the procedure finally adopted was as follows:—

The observer, placed at a distance to give correct perspective, viewed the scene for five minutes (or more in the case of moonlight levels) in order to adapt his eyes to the general level of brightness. The brightnesses of the road and lamps were set by the controller of the experiment, and the observer was asked to adjust the brightness of the sign, which was under his control, to correspond with a particular criterion. With criterion A, he looked straight at the sign, since the minimum brightness for legibility was required; this was, of course, open to the objection that the driver of a car cannot proceed with his eyes glued to a spot some eight feet above the road, but it was considered better to obtain a definite minimum under known conditions than to attempt any arbitrary movement of observer or scene. For criteria B and C, the observer was instructed not to look continually at the sign, but rather to scan the road as if he were driving or riding down it, his attention being drawn to the sign only for so long as was necessary to read it.

On these lines, observers made their choice of brightness for each of three criteria at four background brightness levels:—

A well-lit street, max. road brightness 1.4 e.f.c. (a Group A traffic route).

A poorly lit street, max. road brightness 0.14 e.f.c. (a Group B road).
An unlit street, average scene brightness 0.014 e.f.c. (bright moonlight).
An unlit street, average scene brightness 0.0014 e.f.c. (half moon).

In addition, observers selected sign brightness values with and without the street-lighting sources in operation, giving the effect of "open" and "cut-off" installations. It was found that there was no significant difference in the values chosen.

The complete investigation just described was made with black lettering on a white ground; results were also obtained at the highest and lowest levels with white lettering on a black ground.

(4) Results of Basic Investigation

(i) Sign and Background Brightness

Shorn of all disturbing factors such as glare, the investigation described above shows that criteria B and C are separated by a step of about 10:1 at the highest and about 4:1 at the lowest background brightness. The values for criterion A occur at about 1/10th of the values for criterion C, the "ideal" brightness. The criteria are thus well separated, and no observer confused, by his readings, one level with another. The mean "ideal" brightness rises from about 7 e.f.c. at the lowest to 25 e.f.c. at the highest background brightness, but the detailed results shown in Fig. 3 indicate that a brightness of 15 to 20 e.f.c. lies at the bottom of the range of values chosen as "ideal" for the highest background brightness, and does not encroach on the values considered excessive at the lowest background brightness. In general, observers considered a brightness selected at the lowest level as "ideal" to be perfectly adequate for legibility at the highest, although the value chosen as "ideal" at the latter level was preferable in that the con-

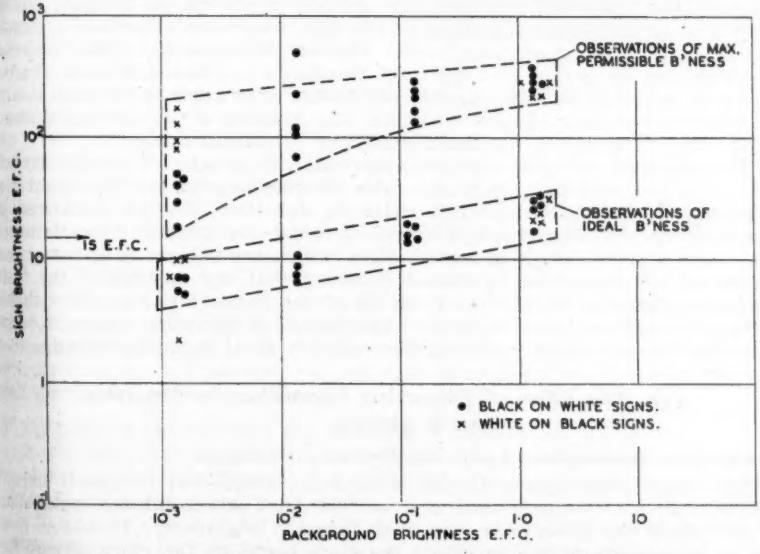

Fig. 3. Relation between sign brightness and background brightness.

spicuity of the sign was then greater. It should also be remembered that at the lowest level headlights would normally be used so that slightly higher values than those chosen as "ideal" for this level are probably required.

At the highest and lowest background levels, and for each criterion, two values are shown for each of four observers: these are values selected for black on white and vice-versa. It will be seen that the values are inextricably mingled, except those for the maximum permissible brightness at the lowest level, where considerably greater values are accepted with white lettering on a black ground. Here observers were guided by loss of background detail due to glare, which was naturally greater with a white than with a black sign.

Beyond the maximum legibility distance a black sign with a white background of brightness 20 e.f.c. can be seen as a distinctive bright rectangle for very great distances; with white letters on a black ground, however, the conspicuity at large distances is very much reduced, and might not be adequate in areas where other signs may confuse the observer.

(2) Legibility Distance, Letter Size, and Coloured Signs

For a traffic sign, it is logical to specify the letter size by the legibility distance required by day: by night the legibility distance should be closely the same. This distance is, of course, controlled by the visual acuity of the observer under the particular brightness conditions obtaining; it is known that visual acuity increases substantially with the logarithm of the object brightness, provided that the surroundings are adequately illuminated. In a night sign, however, the surroundings are dark, and it has been shown ([2]) that with increase in the object brightness, visual acuity rises to a definite maximum and then falls away, as the object becomes more and more glaring.

Thus, once the optimum brightness has been obtained, further increase in legibility distance can result only from the use of larger lettering.

There is nothing to indicate that the maximum distance of legibility is significantly different with black on white or white on black signs, but all observers agreed that the black on white sign was more attractive and gave a more distinctive appearance when viewed momentarily. One observer expressed this by saying that the black words on a white sign were grasped as a whole, while in the other sign the letters had to be appreciated individually. It is possible that this impression (which was obtained at the limiting distance of legibility) was due to the traditional form of printed matter.

The effect of coloured surrounds on legibility distance was also investigated and, provided the brightness ratio between legend and surround was adequate, no change in legibility could be detected. This is confirmed in para. 18 of the 1944 Departmental Report([3]), which recommends black lettering on a white ground except in certain signs which are subject to international agreement. It should be mentioned, however, that one member of the Main Committee signed a reservation (page 58 of the Report) to the effect that a yellow surround may provide better "visibility." If this effect exists, it seems likely that conspicuity is involved: the legibility itself is not increased.

(5) The Effect of Disturbing Factors on the Desirable Sign Brightness

(1) Glare from Street-lighting Lamps and Oncoming Headlights

The initial investigation already described showed that the small amount of discomfort glare experienced in a well-designed street-lighting installation did not affect the observers' choice of "ideal" brightness. However, it is easy to imagine conditions in which the glare could be far more serious; for

example, when a sign is attached to the column of, or placed near a low-mounted lantern, and of course when the observer is subjected to glare from oncoming headlights. The effect of such disturbing sources was therefore studied on the model street scene.

The presence of an adjacent lantern was simulated by a light source placed in turn at (scale) distances of 24 inches and 12 inches from the sign, and as the intensity of this source was increased, observers were asked to say at what level the glare prevented their reading the sign. The results indicated that an intensity of 12,000 candles at 24 inches and 2,000 candles at 12 inches from the sign did not prevent an observer from reading the sign provided that his eye did not first fixate on the glare source. Such fixation gave rise to troublesome after-images, which inevitably interfered with legibility. It is highly improbable that sources of such intensity could appear in such close proximity to a traffic sign, except possibly on bends or gradients, where suitable siting may be used to overcome difficulties.

In experiments on the effect of headlights, reference was made to an investigation(4) by Stiles and Dunbar, which showed that the most serious glare occurs when the observer and oncoming vehicle are separated by about 100 feet, their paths (passing clearance) being some 5 feet apart, a minimum for reasonable safety. Figures were also given for the illumination on the observer's eye from headlamps of the simple parabolic type, and with flat-topped beams. Using this data, two small projectors, adjusted to give respectively the equivalent to scale of 50,000 candles and 25,000 candles directed towards the eye, were placed in front of the street scene at the position corresponding to 100 feet from the observer. It was then possible to read the sign without difficulty at all levels of brightness. An increase in intensity to 100,000 candles, corresponding to simple parabolic reflectors was made: the entire background was then blotted out by glare, but the sign could still be read at 50 yards. However, a sign at the equivalent of 150 yards distance was hardly discernible, since it was both smaller in apparent size and separated from the headlamps by a smaller angle in perspective.

Fig. 4. Simulation of headlights.

It may therefore be said that no glare normally encountered in driving will prevent an observer from reading a sign whose brightness is 20 e.f.c.: however, such glare is extremely distracting, and a sign could be missed altogether. A considerable increase in brightness would be necessary to ensure adequate conspicuity in such circumstances, and such an increase would render the sign itself glaring in normal conditions.

(a) The Effect of Dirt Collection and Reduction in Contrast

It is known that visual acuity is little affected by such changes in average brightness as may be expected on a white sign due to dirt collection if reasonable maintenance is given; such changes are unlikely to reduce the brightness from 20 e.f.c. to less than 10 e.f.c. However, the legibility distance falls as the contrast between legend and surround is reduced, since this involves the contrast sensitivity of the eye. Observations were therefore made on the standard

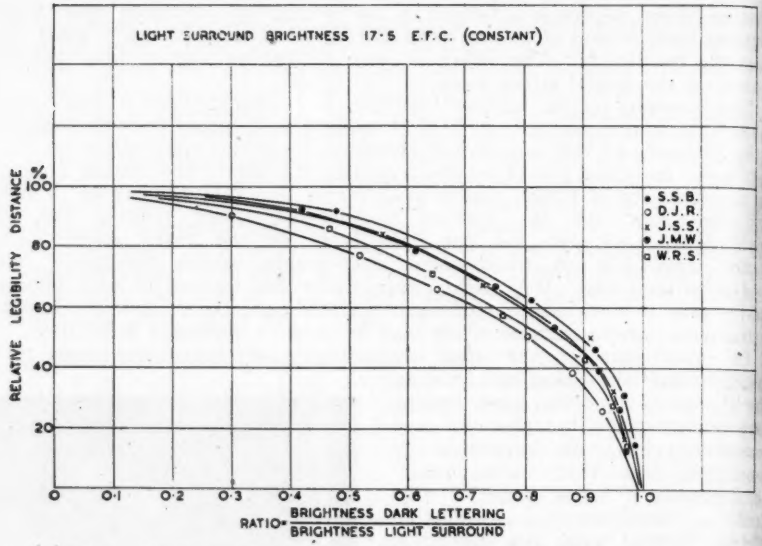

Fig. 5. Relation between relative legibility distance and brightness contrast.

"NO THROUGH ROAD" sign, with equipment (see Appendix II.) which made it possible, while keeping the surround brightness constant, to increase the ratio $\frac{\text{Brightness of Dark Legend}}{\text{Brightness of White Surround}}$ from a very small value (black on white back illuminated) to 1.0 (no contrast). This change in brightness ratio was equivalent to covering the whole sign with an increasing layer of white dust. Observers were asked to select values of this ratio to give threshold legibility at various distances up to that possible with the greatest contrast. The results, seen in Fig. 5, show the distance of the observer from the sign (expressed as a percentage of his distance for maximum contrast) in relation to the brightness ratio selected for threshold legibility. A reduction in distance of 10 per cent. was found to occur with a brightness ratio of between 0.3 and 0.5; this was equivalent to very dirty conditions, in which black letters had a reflectivity of, say, 15 per cent., with a surround reflectivity of 45 per cent. From an examination of ten signs in the Wembley neighbourhood, it appears that such drastic reduction in contrast is unlikely to be found in practice. These signs, of the plain sheet or cast metal type, did not appear to have been cleaned for a long period, yet gave the following data:—

Brightness ratio 0 to 0.1	3 signs
„ „ 0.1 to 0.2	7 „
„ „ more than 0.2	nil

The legibility distance is thus not likely to be markedly affected by normal dirt collection. Nevertheless, the appearance and conspicuity of the sign may be seriously impaired, and the need for regular cleaning is stressed in

the 1944 Report (para. 20), where the importance of servicing the illuminating equipment adequately is also emphasised.

Conclusions

The work described is applicable to areas with normal street lighting, but no attempt has been made to simulate the conditions in shopping areas where confusion with advertising signs and other distractions must inevitably detract from the conspicuity of a traffic sign. Experiments on the effect of glare from headlights show that a sign with a brightness of 15 to 20 e.f.c. is easily legible in shopping areas, but conspicuity is a matter which can best be investigated by full-scale trials.

With the recommended brightness, a sign provides adequate legibility and conspicuity in well-lighted streets, without causing discomfort or disability glare in unlighted or weakly lighted areas where the brightness of the scene is that to be expected in "half-moon" conditions (an illumination of approximately 0.001 foot-candles). At still lower brightness levels it is assumed that headlights would be used, and with such an increase in illumination, the sign would be satisfactory.

Pedestrians should not be caused any discomfort at any level of scene brightness.

The distance of legibility is approximately 50 feet per inch of letter height, using the standard alphabet shown in Appendix I. of the 1944 Report. A small increase in brightness from 20 e.f.c. does not appreciably increase the distance at which the sign can be read, and a large increase reduces this distance.

The maximum distance of legibility is practically the same for black on white or white on black signs, but the black on white sign was found to be more distinctive and attractive; coloured backgrounds have no measurable effect on legibility distance, so long as the brightness ratio between legend and surround is adequate.

As has been said, full scale trials were impossible at the time when this work was going on: in particular, street lighting could not be used. It was possible, however, to make certain experiments in moonlight, and signs of brightness 20, 40, and 60 e.f.c. were viewed against a dark background by members of the Departmental Committee under the chairmanship of Sir Frederick Cook. It was agreed that 20 e.f.c. approaches the upper permissible limit for this background, and also that black lettering on a white ground is preferable to the reverse. Tests with a headlight placed near the sign and directing its beam upon the observers confirmed the laboratory results.

Some of the experimental findings have now been incorporated as recommendations in the Departmental Report on Traffic Signs, 1944, where it is suggested that, except in special circumstances, illuminated signs should consist of a black legend on a white ground, the brightness of this ground being some 15 to 20 e.f.c.; the dangers of lack of uniformity of brightness and of poor maintenance are emphasised. The report further suggests that in any future or revised B.S.Specification for signs, consideration should be given to the quality of materials, the desirable intensity and location of light sources, and to any other matters affecting the illumination of signs.

Finally, the need for full scale trials to confirm or to modify the laboratory finding must not be forgotten. It has not yet been possible to devote sufficient time for a programme of outdoor investigation, but it is hoped that this work will be undertaken in the fairly near future.

PART II.

THE RECOGNITION OF LENSED SYMBOLS

(1) The Problem

This work was carried out to determine whether by simple means certain symbols, described (5) as "not lending themselves readily to the fitting of reflectors," could be delineated satisfactorily. In addition, any suggestions for improving the distinctiveness of signs already fitted with auto-collimating lenses were welcomed.

The recognition of traffic sign symbols must depend on many factors, such as the observer's eyesight, his familiarity with the symbols, the traffic conditions and the siting of the signs. No attempt was made therefore to set a precise figure upon the range at which the various symbols can be recognised: it was enough, under static conditions, to compare the performance of different signs, and to grade them in some order of merit. Changes in the form of symbol or method of lensing could be assessed by their effect upon this order of merit.

The signs singled out as unsuitable for lenses were so described because it was impossible *exactly* to indicate certain complexities of shape, such as the wheels in the locomotive symbol (for level crossings) and the arrow heads in the symbol for a roundabout: as will be seen, this difficulty can largely be overcome by modifications, or by approximation of the lens system to the daylight appearance of the sign.

(2) Experimental Technique

The Ministry of Transport supplied two full size copies each of eighteen typical signs. One from each pair was equipped with reflecting lenses according to the method recommended in B.S.S. 873-1939 where applicable, and in other cases after preliminary observation and modification.

Simultaneous observations of the symbols were made by ten observers, drawn from the Ministry and laboratory staff: the observers sat overlooking open ground on which the signs were exposed. The signs were shown in turn, first at 200 yds. distance, then at 150 yds., 125 yds., 100 yds., 80 yds., 60 yds. and 50 yds.: they were exposed for a period of ten seconds each, in a different (random) order at each station. Each observer kept his own record on a blank form prepared for the purpose, on which he entered, in the order of their appearance, the symbols recognised (or thought to be recognised) at each station. The controller of the experiment observed with field glasses and made a master copy with which to check each observer's results. No one at the viewing end knew what sign would appear next.

An arbitrary method of assessment was used: for each observer, symbols identified at the most distant station at which he recognised any were allotted one point: additional symbols identified at the next station were allotted two points each; additional symbols at the next station three points, and so on. The sign most easily recognised thus scored the lowest number of points, and it was possible to grade signs in an order of merit. The numerical value of points "won" by any symbol has of course no significance, but the system com-

pensated to a great extent for variation in the observer's eyesight and familiarity with the symbols.

The record cards also provided information on the confusion to be expected between certain symbols.

The procedure outlined above was followed

(1) by daylight, with plain signs,
(2) by daylight, with lensed signs,
(3) at night, with plain signs } in the beam of a headlight.
(4) at night, with lensed signs }

(3) Results of Recognition Tests

(1.) General

It was expected that great variation between observers in range of recognition would be found: some identified all symbols at 200 yards in daylight, while others were not definite for all symbols until the range was reduced to 100 yards. An even greater variation may be expected at night, when the strain of driving affects certain individuals more than others. The variation is due chiefly to difference in

(1) eyesight,
(2) familiarity with symbols,
(3) criteria (depending on the natural caution of the observer).

It is thus not possible to give precise figures for the distance of recognition of individual signs; at best, ranges can be approximate only and for static conditions.

Before giving an account of the performance of the signs, a modification made to the locomotive symbol after preliminary tests should be mentioned: the smoke from the engine was raised to about 45 deg. to the horizontal, and three large wheels were indicated by lenses, superimposed on the existing five. Two new symbols, "Two-way Road" and "Hump Bridge" were also examined (see 1944 Report): otherwise, symbols were as previously laid down.(6)

(2.) Recognition by Day

Detail in the symbols (such as the wheels of the locomotive, the individual flames in the torch, and the breaks in the circle indicating roundabout) was found to be of no value for identification at the useful ranges of 150 to 200 yards, yet the symbols themselves were recognised. This led to the conclusion that with a lens system symbols whose details cannot be shown may well be identified, since even by day such detail is not necessary for recognition. The sole requirement is that any modification or system of lenses should emphasise the salient features of the symbol: alteration of detail is useless.

In order to determine whether the fitting of lenses has an appreciable effect on recognition range by day, observations were made on the lensed signs by daylight, but no significant change was detectable in distances for certain recognition. The effect of the lenses at limiting ranges is to reduce slightly the contrast between the symbol and its surround; this was noticeable in a sign bearing the legend "Pedestrian Crossing Ahead," which was prepared to expose the effect of "heavy" lensing on letters. The distance for certain legibility was not significantly affected.

(3.) Recognition of Symbols by Night

As has been said, no attempt was made to indicate detail on complicated symbols by means of lenses, but merely to emphasise salient features and distinctive geometric form. Thus, a plain circle of lenses was easily identified as a

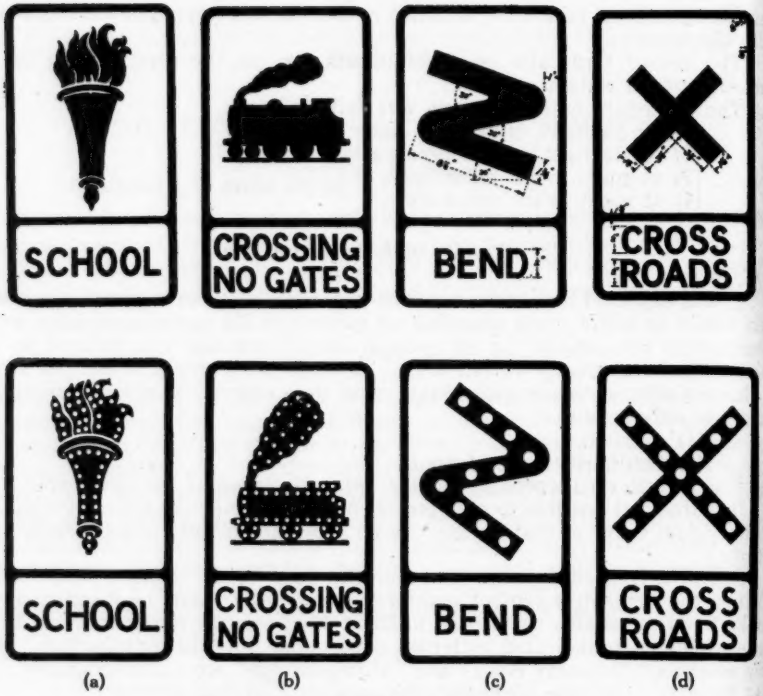

Fig. 6. Typical modifications to symbols.

(a) Symbol unchanged; no attempt to indicate detail in flames.
(b) Symbol modified to be more distinctive and to simplify lensing.
(c) Symbol modified to be more distinctive; increase in angle between strokes.
(d) Symbol modified to be more distinctive; increase in length of strokes.

roundabout sign, although in fact the circle is broken, and arrowheads exist: similarly, it was found that, by indicating three large flames, the torch symbol was easily recognised. In Fig 6 some of the old are compared with the new symbols more suitable for lensing, as recommended in the 1944 Report, based on suggestions arising out of the experiments here described.

For a normal observer, the recognition range was found to be from about 150 yds. for the best to 100 yds. for the worst symbol, distances some 50 yds. less than were possible in daylight: the lensed signs were generally recognisable even when well outside the beam of the headlight.

With unlensed signs, recognition is affected not only by the observer's characteristics, but also by unpredictable variations in headlight distribution and direction and by the natural features of the road. From static tests alone, therefore, no complete guide to practical performance can be deduced. With a stationary beam of 10^5 max. candlepower, aimed directly at the signs, the recognition distance was rather less than that with lensed signs, and when the

beam was agitated, certain recognition was very difficult: lensed symbols, however, were still easily identified.

Conclusions

The modifications made to symbols previously described as unsuitable for lenses have rendered such symbols as recognisable as the more simple signs of distinctive geometric form, and small changes to these simpler signs have made them more easy to identify. The changes can be examined by comparing the 1944 Departmental Report with the Traffic Signs Provisional Regulations of 1933.

No investigation of the merits of different designs of reflecting lenses was made, since only comparative results were required, but it was recommended in the 1944 Report that the British Standards Institution should be asked to prepare a specification for the optical properties of auto-collimating lenses for traffic signs.

APPENDIX I.

CORRELATION BETWEEN EXPERIMENTAL RESULTS AND EXISTING DATA

It is interesting to compare the experimental results with previously known data obtained under controlled laboratory conditions. In no case does the experimental technique used in this investigation correspond exactly with the idealised conditions obtaining in the fundamental work previously undertaken, but the agreement shows that such fundamental data can be applied with considerable success to practical conditions.

(1.) Optimum Brightness

Lythgoe[2] has given data on the change of visual acuity with object brightness, the object being seen against a dark background. The greatest visual acuity was found to occur with an object brightness of 10 to 20 e.f.c.

(2.) Upper Brightness Limit

Holliday, in his investigation[7] of the glare acceptable to an observer adapted to a given brightness level, who then is suddenly confronted by a source of high brightness, gives the relation:—

$K = \log B + 0.25 \log Q - 0.3 \log F$ where

B = source brightness in millilamberts.
F = adapting field brightness in millilamberts.
K = 1.9 for the comfort/discomfort threshold.
Q = solid angle subtended at the eye by the glare source.

Considering a sign 14 in. x 21 in., at a distance of 150 ft., and taking the adapting field brightness as about one-half of the maximum road brightness, we obtain, using the appropriate units, the following values for the maximum acceptable sign brightness.

Max. road brightness (e.f.c.)		1.4	0.14	0.014
Max. acceptable sign brightness (e.f.c.)	From Holliday's Formula	600	275	125
	From direct experiment	350	200	100

The agreement shown in this table, though by no means exact, is sur-

prisingly close considering the subjective judgment involved. A small change in the value of K would make the agreement very close.

Luckeish and Moss([8]) give data which suggest a sign brightness of about 250 and 125 e.f.c. for discomfort threshold at the two upper levels of source brightness investigated; in this work the criterion was chosen for minimum perceptible discomfort, and the values of acceptable brightness are probably lower than would be satisfactory in practice.

(3.) Legibility Distance and Contrast

Luckeish([9]) has studied the relation between visual acuity and contrast. His experiments are of the same nature as those involved in obtaining the change in legibility distance with varying contrast, although it seems doubtful whether it is legitimate to term the quantity measured "visual acuity" as the contrast sensitivity of the eye is also involved. However, it is legitimate to compare the results, since the experimental conditions were similar, and this comparison is made in Fig. 7. The agreement is extremely close.

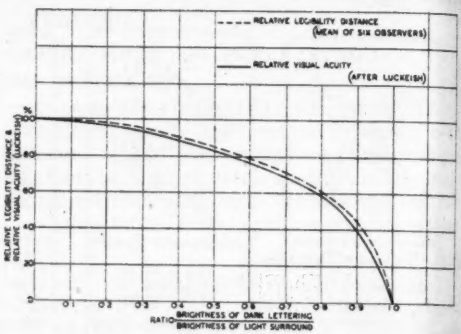

Fig. 7. Relation between relative visual acuity (Luckeish), relative legibility distance and brightness contrast.

(4.) Coloured Signs

Many workers have studied the effect of coloured light on visual acuity, and found that acuity is appreciably lower under red and (especially) blue light than under white or under light from the middle region of the visible spectrum. This indicates that black lettering on a blue or red ground is undesirable in a sign, though it does not necessarily follow that a white legend on a red or blue ground is necessarily inferior to a white legend on a black ground.

It might indeed be thought that some additive effect of brightness discrimination and hue discrimination would occur with a white or coloured legend on a coloured ground: very little work has been done on this problem, and then only with target and ground of equal brightness though different in colours: in a sign such equality of brightness does not exist.

It may, therefore, be said that no evidence exists favouring the use of colours for signs, if legibility only is considered; the findings of the 1944 Report, based on practical observations, bear out this view.

For a discussion of the factors affecting visual acuity reference may be made to a paper on "Human Visual Resolution,"([10]) where a full bibliography will be found.

From the above it is apparent that, apart from the disturbing effects of glare, it would have been possible to select a sign brightness of some 15/20 e.f.c. to determine reasonably closely the upper brightness levels permissible, and to deduce the effect of dirt on the sign.

However, it will be generally agreed that the technique adopted, more

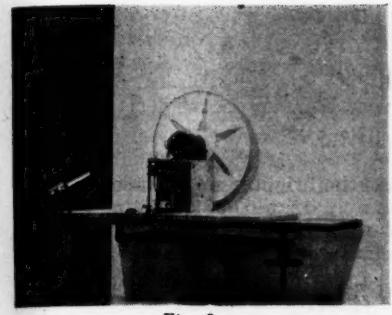

Fig. 8

Fig. 9.

Figs. 8 and 9. Method of varying-sign contrast.

closely approaching practical conditions, has advantages where observations and assessment by those not familiar with laboratory work are involved. Indeed, without such tests, it is doubtful whether the recommendations would have carried much weight.

APPENDIX II.

APPARATUS FOR VARYING BRIGHTNESS CONTRAST OF MODEL SIGNS

Fig. 8 and Fig. 9 show the arrangement used to vary the brightness contrast of the sign in experiments on the variation of legibility distance with brightness ratio.

The sign, backed by an opal panel illuminated by a suitable lamphouse, is mounted flush with a large screen, upon which a picture of a street scene can be projected in the usual way. A few inches in front of the sign and screen is a rotating disc upon a table adjustable vertically relative to the sign. This disc has cut in it six triangular apertures as shown in Fig. 8, so that when the table is raised until the bases of the triangular apertures pass before the sign, the transmission of the disc is high, and when the table is lowered, the transmission decreases to zero. Thus the apparent brightness of the sign, viewed through the disc, can be varied from about 80 per cent. of its actual value to zero.

A small projector throws upon the front of the disc a patch of light of the same size as the sign, so that when viewed from in front the patch of light is superimposed on the sign. The offset and orientation of the projector is such that light from it passing through the rotating disc does not fall on, but alongside, the sign. The brightness of the patch of light is adjusted to be equal to that of the light parts of the sign. If this brightness be B_L, and the transmission of the disc be T, (at any one setting of the table) then the apparent brightness B_1 of the sign is the sum of contributions from the sign (seen through the disc) and that from the disc itself, or

$$B_1 = B_L \times T + B_L(1 - T)$$
$$= B_L$$

The apparent brightness of the light parts of the sign is thus constant.

The apparent brightness B_2 of the dark legend is

$$B_2 = B_D \times T + B_L(1 - T)$$

where B_D is the true brightness of the legend.

Thus the brightness ratio of dark to light parts is

$$\frac{B_2}{B_1} = \frac{B_D \times T + B_L (1 - T)}{B_L}$$

For the internally illuminated sign used B_D may be neglected, and the brightness ratio becomes

$$B_2/B_1 = 1 - T$$

Thus for any vertical setting of the disc, the brightness ratio may be found from the transmission at that setting. This may be calculated for any radius R on the disc, being equal to the sum of the arcs intercepted by the apertures on a circle of radius R, divided by the circumference of that circle.

The transmission of the disc at any setting is different for the top and bottom of the sign. It is necessary for the observer to consider one word only (here THROUGH), to avoid error from this effect. With the height of letter used (¼ in.) and the size of the disc used (D = 24 in.), no apparent variation in brightness over the word THROUGH was discernible.

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Discussion

Mr. A. E. N. Taylor (Ministry of Transport), after congratulating the author and his colleagues on their very novel method of attack upon this problem, said that past practice when framing regulations or specifications in regard to illumination, was to say that the sign should be adequately illuminated, or visible from a reasonable distance. That attitude was very dear to the hearts of legal draughtsmen and, in the past, it had been the only method by which to convey something of the performance. The investigation dealt with in this paper, however, was the first step towards a more precise specification of what was needed, but he was not prepared to say whether the legal draughtsmen would continue to have their way and retain the old form of wording or whether the technical side would now have its way. Nevertheless, even if the technical side did not get its own way, these investigations would be a very valuable guide to the sign manufacturer. It was not realised, perhaps, that the Departmental Committee had recommended a sign brightness of 8 e.f.c., for bollards—a traffic sign—and 15 to 20 e.f.c. for other traffic signs, but he thought that difference could be explained and justified.

The Ministry had recently been making some investigations into bollard lighting, with the co-operation of the General Electric Co. and the Gas Light and Coke Co., and had found that an average brightness of 12 to 30 e.f.c. gave reasonable results. This lined up very well with laboratory work and there

was reason to have every confidence that the practical tests when made would fully support the work done by the author and his colleagues in the laboratory.

Dealing with one or two matters of detail, he did not think the recommendations in the Departmental Committee's Report went quite far enough. There must be some tolerance to what was specified, and he did not think it should be said that the signs should have an average brightness of, say, 17 e.f.c. There must be some upper and lower limit to provide a range suitable for manufacturing purposes. In connection with the bollard investigation, it was felt it would be safe to specify a range from 5 to 30 e.f.c.

As regards uniformity, it was felt there must be some sacrifice of uniformity. The Street Lighting Committee had said 4 : 1, and the recent measurements suggested it would be possible to go to 16 : 1. He thought the peak should be three times the maximum and for bollards the figure for uniformity might be 15 : 1. Taking an average figure of 17 e.f.c., for brightness as found in the bollard investigations, and applying the same thoughts to signs, the range of brightness would be from 10 to 50 e.f.c., and the uniformity ratio would be 15 : 1. However, he would like the author's view as to whether that would be acceptable, because, whereas a bollard was merely an obstruction in the roadway, the sign conveyed some definite information to the road user. Three times the maximum of 50 e.f.c., in the case of signs was 150 e.f.c., and therefore he would like the author's views as to whether the figures just quoted would be satisfactory as a practical specification for traffic signs, if it were found possible to give some precise figures for sign brightness.

The paper referred to the recommendation of the Departmental Committee that some practical tests should be made as soon as possible to test the results found in the laboratory. It had not yet been found possible to give sufficient time to outdoor investigations but it was hoped this would be possible in the future. Those concerned in the Department had made a start and would welcome the co-operation of the author and his colleagues.

There was one recommendation in the Report of the Departmental Committee with regard to a sign to indicate a swing bridge and where to stop. The Report said that the sign should be illuminated by day and by night and that when it was not illuminated, the legend should be invisible. It had not yet been possible to find a sign which would have sufficient brightness by day and yet would not be dazzling by night, and further would show the words "Stop" or "Swing Bridge" in red letters on a white ground clearly when illuminated and yet would show nothing at all when the illumination was extinguished. As a stop-gap an ordinary red traffic signal above a sign which had the words "swing bridge" was operated when it was desired that the traffic should stop. If the author or his colleagues could help in getting a suitable sign, they at the Ministry would be very glad.

Mr. C. J. W. GRIEVESON said he was greatly interested as an ordinary user of the road. Although the public heard a great deal about road accidents, they were apt to be a little insensitive unless an accident concerned themselves personally or some of their friends. In the case of most road accidents it was reported that the driver hesitated, the pedestrian hesitated, or the cyclist hesitated, and anything which would reduce this period of hesitation would benefit everybody on the roads. He welcomed the investigation reported in the paper as a contribution in that direction. He had been surprised on several occasions at the carelessness, even stupidity, with which certain traffic signs had been erected. There was one not very far from where he worked, which was

in accordance with the specification as far as size and position on the kerb were concerned, but it was put some two yards in front of an ordinary street lamp, which at night outlined the top of the sign but made the legend unreadable. No doubt others could supply examples of the same kind.

He was interested to note that the Sub-Committee had not found any advantage in the stencil type of sign with white letters on a dark ground. Unsatisfactory signs of that type were not uncommon, such as the usual "Road Up" sign used by excavators, with cut-out letters lit by a single hurricane lamp. The L.P.T.B. might take notice of the findings in the Report on that point, with advantage to the legibility of the destination boards of buses and trolley-buses.

He was glad to have heard the paper, because he had been a member of the B.S.I. Sub-Committee that before the war was considering the lensing of signs. That committee was able to get a bit further than the authors of the paper; there were no lighting restrictions in those days, and the members were able to spend a couple of evenings careering around roads at the N.P.L. judging lens patterns in a practical way. One thing that he would have liked to see in the present paper was a picture of the lensing seen by reflection from a headlight, without the help of the daylight appearance. That was the best test of the effectiveness of the lens pattern.

The distance at which a sign became legible depended on its setting relative to the approaching headlight. There was no explicit statement in the paper as to the position in which the signs were placed for the test.

Those who had had experience of reflecting signs knew that the direction of the axis of the lens with respect to the headlights and with respect to the direction of view was important, and probably when this work was applied there would have to be some specification with regard to that. As the car approached it, the sign became brighter, then faded, and finally disappeared as the car passed. How far away should the car be when the brightness of the sign was a maximum? How near should the car be when the sign disappeared?

This paper did not answer all the questions that could be asked, but it made some advance towards a solution of these problems in having found a definite value of brightness of an un-lensed sign that was not glaring in an unlighted street and was good in a lighted street; that was a worth-while achievement.

Sir Clifford Paterson F.R.S. said he had nothing but admiration for the advances that had been made since he himself worked on similar problems nearly half a century ago at the N.P.L. He had been struck by the ingenuity and effectiveness with which the authors had reproduced practical conditions in the laboratory. Tactics such as these were the key to so many researches which were carried out in connection with illumination. He recalled many such investigations. There was an early one in which he was personally engaged with Dr. Dudding—and he was not sure that Dr. Walsh was not in the background as a junior assistant. They were trying to measure in the open the visibility of point sources of light with the object of ensuring that a ship's light might be "visible on a clear, dark night," at a distance of two miles. This experiment was tried in Bushey Park at night, but it was not possible to get any results owing to the variable conditions. Then they viewed sources of light over a two-mile range from Richmond Hill on a freezing, but clear night and obtained data which convinced the sea captains that the laboratory results could be trusted.

There had also been other notable experiments of the same nature. For

instance, the development of star-light street lighting, under blackout conditions, was completed almost entirely by simulating outdoor conditions in the laboratory. Many problems in connection with street lighting and visibility had been dealt with in the same way. This present work on traffic signs was another example of the same thing. He believed that this sort of technique was one with which we were most likely to succeed in our efforts to solve many recalcitrant and difficult problems; problems which seemed intractable until things were under complete control in the laboratory.

Mr. R. PELERIN asked whether any observations had been taken through the windscreen of a car. He said the average windscreen was seldom clean, and even when it was well cleaned, the transmission was never 100 per cent. Did the author consider that the limits recommended for brightness took account of that aspect?

Secondly, he said, the tendency now is to use smaller cars for economic reasons, and consequently springing is not perfect. Had any observations been taken with the observers on a vibrating platform, because such conditions are likely to be encountered when approaching cross-roads or a roundabout?

Mr. W. HADFIELD said that many practical road traffic signs were not simple rectangles, as used in the experiments, but were surmounted by a disc, ring, or triangle; also in many cases the main plate comprised a large symbol with small lettering beneath, which lettering was mainly instructional in purpose and so need not be legible at night. The practical need in the case of such signs was identification rather than legibility, and this hardly needed uniform illumination of the whole sign combination at 15 e.f.c.

The sign used in the experiments had an area of about 2 sq. ft. Some approach direction signs might have an area of approximately 30 sq. ft. Was it necessary to illuminate the large area sign to the same intensity as the small area one?

An important practical problem was the economic attainment of the illumination recommended. Two light sources were normally regarded as necessary in case one failed, but it was obviously undesirable to multiply the number of light sources. Could a 30 sq. ft. sign be illuminated to the standards advocated without multiple sources or other expensive equipment? Information would be welcomed about a practical and inexpensive method of providing suitable illumination on the various types and sizes of signs used on the road.

Referring to the symbols on signs, he said the torch was probably the one which had been most criticised from the point of view of reflectors. Mr. Stevens had referred to it being considered effective at night provided it was shaped somewhat similar to an ice cream cornet. If the top had been made round and smooth like the top of an ice cream cornet, instead of endeavouring to show several flames, it would have been easier from the reflector point of view.

Mr. R. S. BRADLEY said that some of the lesser but nevertheless important duties of a Public Lighting Engineer were in connection with lighting of traffic signs which had been made difficult by the lack of suitable equipment. For some years before the war, he had tried to get manufacturers to look into this matter, but with little success. He welcomed this communication from a member of one of the larger research laboratories indicating that in the future, lighting fittings designed on sound principles would be available.

The committee responsible for the 1944 Report on Traffic Signs were of

the opinion that external illumination of signs was preferable to internal illumination because of their greater ease of maintenance, simplicity, and better daytime appearance. He did not agree with this view, as he had found that external lighting was much more expensive in maintenance.

The sign itself was of painted board variety; it soon deteriorated, and the lighting fitting, as was seen during the war, needed constant attention. To avoid distracting reflections, matt paints were used, but these did not seem to be obtainable in a durable form. However efficient and ingenious the design might be, unless it could be efficiently and economically maintained it could not be accepted.

He agreed that box sign design to date had a poor daytime performance, but this need not continue to be the case. Had the author been able to test the effect of using raised letters, say ¼-in. thick, with 6-in. letters, on suitable plastic instead of glass? His own preliminary experiments indicated that this was superior to the stencil or painted legend.

He agreed with the author that the compressed alphabet was most unsatisfactory. Where the maximum reading distance was taken as 250 ft. with 6-in. letters he found that the standard alphabet had to be used with a spacing between letters not less than 1 in.-1½ in. This did, of course, give rise to a rather large sign, but in turn brought advantages in ease of construction and maintenance.

In conclusion, he hoped that the author would be able to continue his inquiries into this small but important field of illuminating engineering.

Mr. P. S. BARTON said that if this work could be pressed on with, it should be possible to develop other ideas which could be placed before the authorities and be of great service in regard to road safety and the prevention of accidents. He had occasion recently to make a protest with regard to bollards. On a certain main road there were eleven temporary pedestrian crossings, each illuminated by four hurricane lamps. Apparently these lamps were not expected to be kept burning all night, and on one occasion he found that on nine out of the eleven all the lamps were out and the crossings were completely unilluminated. The street lighting was a very fine example of mercury vapour lighting, and headlights were not needed in the ordinary way, but now one was liable to run into one of these obstructions unawares. He went to the local police station and complained, and to his astonishment they told him it did not matter if one of these obstructions was knocked down as they were only temporary and could easily be replaced! When the permanent bollards were erected the public would by then be used to them being there. Apparently, until an accident occurred nothing could be done. The matter was not in the hands of the police, but of the local council, who maintained the lighting.

Mr. G. E. V. LAMBERT said that, although he did not wish to comment on the paper, he would like, as an ordinary road user, to add emphasis to Mr. Grieveson's remarks on the question of the siting of traffic signs. Many signs, he said, were inclined at the wrong angle, especially those which were intended to be read in the light from car headlamps. Many of the direction signs were made of enamelled iron which, of course, has a highly specular surface, and a large number were so placed that the light from a headlamp could be reflected to the driver's eyes, thus greatly impairing the legibility of the signs. There seemed to be a general impression that traffic signs should be tilted towards

the road to render them more legible. While this was probably true in daytime, to avoid glaring specular reflections from headlamps, they should be inclined, if anything, slightly away from the road. This point does not appear to have been mentioned in the Ministry of Transport 1944 Report of the Departmental Committee on Traffic Signs.

Mr. J. W. BORMAN asked the author if he had considered the effect of 15 e.f.c., with a glazed front panel beneath the sign, as there was in the "Keep Left" sign, on bollards. Would a higher degree of illumination be required to avoid glare?

Mr. K. L. KELLY said that, as representing the Automobile Association, he could, to some extent, speak on behalf of "the customer," or road user. He did not think the average motorist was at all aware that behind the scenes the back-room boys were going ahead with these experiments with a view to producing signs which would be of greater assistance to him. He entirely agreed with the previous speakers who had spoken as road users, and to their comments he would ask the author whether he had considered in some detail the importance of conspicuity. It was referred to in the paper, but one of the most important functions of a road sign was that it should be readily visible. The motorist was charged with the responsibility for keeping a lookout for road signs. It was his responsibility to see them if they were there, but in urban areas, where there were so many distracting factors, it was a very easy thing even for the most careful motorist to miss seeing a road sign until he was so close to it that, with his speed, he had not time to take it in. He was referring more particularly to direction signs, and he put in a plea for the conspicuity of traffic signs to be looked upon as a matter of prime importance so that the motorist would be made aware, at the earliest possible moment, that there was a sign for him to observe.

Mr. A. CUNNINGTON, referring to the compressed alphabet and the importance of proper spacing, said that many years ago he took this matter up with sign makers, and he rather gathered they were completely satisfied that their draughtsmen knew all about it. They asked for a free hand and said they would ensure that the signs would be legible, but the makers had no scientific background as to the thickness of letters or distance apart. It was true that the draughtsman had, in some sort of empirical way, arrived at something which was satisfactory, and the firm's reputation as sign makers depended on the fact that they could make clear signs. However, he felt there was scope for more research towards a really scientific basis for the *display* of lettering to make it of maximum legibility. Had anything been done in that direction apart from the standard alphabet, or was he right in thinking it was largely a matter of trial and error?

Another matter of interest to him was the use of black on white or white on black. On the old South-Western Railway it was discussed, and some elementary experiments were tried some 30 years ago. The conclusion was that there was not much in it. Personally, however, he thought there was a good deal to be said for white lettering on a black background with the ordinary box sign, from the point of view of *conspicuity*. There was a notable example of that on the L.P.T.B. stations, and he did not think it was just a matter of chance that their "Way Out" signs were always illuminated white letters on a black background. He thought the reason was that in a Tube station where there were a large number of advertisement signs, it was useful for the

passenger to see readily the "way out" sign. Looking along a platform, the first thing that impressed one was the white lettering on the black background and that was undoubtedly an advantage. He had used the white on black box sign a good deal at surface stations, partly because he thought it was the simplest way of lighting.

Reference had been made to tolerances, and presumably the idea was to assist the manufacturer in getting the desired results, but personally he deprecated making the tolerance so large as to allow for what might be called inferior signs. Surely illuminating engineers now had sufficient experience with regard to things of that kind that they could, without any very alarming expenditure, get really good uniformity of illumination. He suggested that sign makers should be kept "up to scratch" by keeping the tolerance as low as possible.

Mr. J. M. WALDRAM queried the maximum brightness ratio of 15:1, referred to by Mr. Taylor, as being too large; much lower brightness ratios could be simply achieved, and he thought that so large a value would lead to patchy and illegible signs. He doubted, however, whether the degree of uniformity could properly be specified by a simple brightness ratio; it was evident that the angular rate of change of brightness (referred to the observer's eye) was important. A box sign lit by one or two lamps spaced well apart and producing a non-uniform brightness was easily legible from close to the sign and the non-uniformity was imperceptible; from greater distances the legend tended to disappear, and all that could be seen were the bright patches associated with each lamp. In the two positions the brightnesses and brightness ratios remained the same, but the angular rate of change of brightness was increased proportionately to the observer's distance.

Mr. TAYLOR pointed out that he had suggested 15:1 for bollards, and was inquiring whether it would be satisfactory for signs. He did not know whether it would be.

THE PRESIDENT raised the question of how far the conclusions arrived at in this particular investigation would apply to other problems. There was sometimes the danger that a definite conclusion once reached was looked upon as being universally applicable. In the case of these signs, there were two functions served by the brightness afforded—to enable detail to be seen and to arrest attention. In the case of traffic signs there was no detail to be distinguished; all that was necessary was to attract attention. In the case of signs for purposes other than those considered in this paper, such as advertising signs or signs indicating destination or departments in a store, different conclusions might possibly be arrived at. There was certainly one type of sign which would present a different problem, namely, that in which the detail did not consist of pure black and white and which involved relatively small differences of contrast. In that case, as in pictorial signs, the level of illumination might need to be raised to enable the picture to become evident at a sufficient distance. It might also be found that in such cases the background was very much more important. The diagram of Lythgoe, to which the authors had referred, was based essentially on the perception of small changes of brightness (light and shade) which the brightness of the background might materially

influence—much more so than in cases where one was primarily dealing with silhouette.

Mr. STEVENS said he would leave it to Mr. Smyth to reply in full to the discussion, but there were one or two points he would like to deal with.

In the first place, he said, there must be a careful distinction between the work reported in this paper and the M.O.T. Report. The M.O.T. Committee took the results and interpreted them in the light of their experience with road traffic and the like. Therefore, this paper must not be held responsible for the results as given in that Report. He made the point because he felt it would make clear some other things that had arisen in the discussion.

As regards Mr. Taylor's remarks, he agreed with Mr. Waldram that the 15:1 value for bollards was rather too big a range, at all events for the smaller signs. As regards the 5 to 30 limits for brightness, Mr. Weston had just reminded him that this was 2 : 1 on a log scale and probably represented a fairly definite step in visual perception.

Several speakers had referred to the merits of white on black or black on white signs. In the laboratory it had been found that the black on white was a cleaner looking affair.

With regard to lensing, nobody, of course, believed that this problem had been finally solved or that the M.O.T. had solved it. The paper merely dealt with some aspects of this problem.

In reply to Mr. Pelerin, he said that no observations were carried out through a windscreen, but he would have thought that the results now reported were reasonably valid in so far as dirt on the windscreen reduced contrast because of the subsidiary experiment on the effect of dirt on signs. However, the effect of the windscreen was the sort of thing that only practical tests could decide.

The comparative performance of internal and external lighted signs was not properly within the terms of reference of this investigation, but those concerned with this work could not help drawing some conclusions. It was felt that internally illuminated signs gave a better contrast and better colour by night. However, the effect of dirt collection tended to be severe on internal illumination and there were, of course, practical considerations such as the difficulty in making large signs with internal illumination. Moreover, such signs would be very vulnerable to small boys!

As usual, the President at the end had applied a valuable corrective when he suggested that these results should not be interpreted as applying to all sorts of conditions. That was perfectly right. However, that was not to say that these results could not be useful in giving a lead in some other problem.

Mr. SMYTH, in a written reply to the discussion, regretted his absence from the presentation of the paper. After reading the discussion, his clearest impression was that someone would have to do a lot more work. It was right, as Mr. Stevens had emphasised, that the work described had been submitted to the M.O.T. for approval, and the conclusions were not necessarily adopted for recommendation in the Report. The work had been restricted to an investigation of the optimum brightness of a *uniform* sign bearing a legend in the standard alphabet, and to methods of fitting lenses for easier recognition of symbols. No attempt had been made to assess the merits of different designs of lens, or to carry out dynamic tests.

Perhaps the most needed "follow up" would be the investigation of the permissible departure from uniformity in brightness: he thought that

a variation of 15 to 1 would be excessive, and tentatively suggested something nearer 4 to 1—but he had no great evidence to advance. As Mr. Waldram had said, the rate of change of brightness across the sign was also likely to be important.

Mr. Taylor's results on the acceptable brightness were very helpful: the author and his colleagues had also measured the brightness of a number of KEEP LEFT legends, and their conclusion had been that 5 to 30 e.f.c. was the acceptable range, exactly the same as Mr. Taylor's figures. It seemed that uniformity and letter spacing were at least as important as the mean brightness. There was some reason to believe that a range of 5 to 30 e.f.c. should be acceptable: firstly, observers in the laboratory had agreed that a brightness within this range, chosen at any background level as ideal, was acceptable at the other levels: secondly, as Mr. Weston had pointed out, on a log-scale the ratio was about 2 to 1, which is normally considered the step needed to make an easily appreciated difference in visual effect.

Several speakers had referred to the construction, size and type of signs. The results presented had been obtained at a distance of 50 ft. for each inch of letter height, and could be applied to any size of lettering at this distance; clearly, an increase in size of sign to carry a longer legend would not affect the ideal brightness. It was realised that there were difficulties in the illumination of a large sign, but these difficulties were not taken into account in suggesting the ideal brightness. As for power, with internal illumination 10 watts per sq. ft. was ample; a sign 30 sq. ft. in area would therefore consume less than the average streetlighting lantern, and it could not be argued that a traffic sign was of less importance than a single lamp post.

It had been suggested that where a symbol is used, it was unnecessary to light the interpretive legend: the author could not agree with this, as the clear outline of a rectangular sign provides much of its conspicuity. Conspicuity certainly needed study, though no one had suggested a reasonable way of measuring it. Clearly, siting was a major factor, and common sense rules could be laid down. In areas with many advertisements, it might well be, as Mr. Cunnington suggested, that a white on black sign would be more conspicuous: however, if a choice of one type had to be made, the ease of reading and greater conspicuity at great distances of the black on white sign made it preferable.

In their report to the M.O.T., the technical committee had suggested the pros and cons of internal and external illumination, but had not been able to recommend either method definitely—the recommendation for external illumination was the decision of the M.O.T. Mr. Bradley's comments were interesting. The author had not made any tests with raised lettering, but had used opaque letters on a white opal glass sheet: it seemed inevitable that the contrast of an internally illuminated sign would be degraded in daylight, as the reflectivity of opal glazing could never reach that of an opaque reflector such as vitreous enamel.

As Mr. Pelerin and Mr. Grieveson pointed out, there was a great deal of work to be done on the dynamic effects which existed, particularly with lensed symbols. The sub-committee's work, however, had been directed to the selection of easily recognisable patterns: these had been viewed (at full scale) from 200 yards down, and the conditions of brightness had therefore varied over a wide range. Much could doubtless be done on the design of lenses, but any such improvements were unlikely to alter conclusions on the best layout for any particular symbol.

Additions to List of Members

The following applicants have been duly elected by the Council to membership in the Society, and their names have been added to the list of members:—

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SESSIONAL MEETING IN LONDON

A sessional meeting was held at the Royal Society of Arts, John Adam Street, Adelphi, London, W.C.2, at 6 p.m. on Tuesday, February 11, 1947.

Mr. J. S. Dow (President) was in the chair.

The minutes of the last meeting having been taken as read and confirmed, the President called upon Mr. W. R. Stevens (in the absence of Mr. J. S. Smyth due to indisposition) to present the paper entitled "The Brightness and Legibility at Night of Road Traffic Signs."

The paper reviewed the work of the technical sub-committee, appointed by the I.E.S. at the request of the Ministry of Transport, whose report was presented in 1944. Mention was made of the experimental technique employed in this work, the consideration of the many factors involved, and the results of the investigations.

After a vote of thanks, proposed by the President, had been carried, the discussion was opened by Mr. A. E. N. Taylor, who was followed by Mr. C. J. W. Grieveson, Sir Clifford C. Paterson, Mr. R. Pelerin, Mr. W. Hadfield, Mr. R. S. Bradley, Mr. P. S. Barton, Mr. G. E. V. Lambert, Mr. J. H. Burman, Mr. V. L. Kelly, Mr. A. Cunnington, Mr. J. M. Waldram, and Mr. J. S. Dow. After Mr. Stevens had replied to the discussion the meeting was terminated.

The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

With a view to avoiding possible confusion with other publications, reference to these Transactions should be in the form:—"Trans. Illum. Eng. Soc. (London)."

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